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Farmer and Farmland Owner Views on Spatial Targeting for Soil Conservation and Water Quality

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Abstract

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Keywords

Best management practices (BMP), Environmental benefits, Spatially targeted conservation, U.S. Corn Belt, Water quality

Disciplines

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Comments

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Farmer and Farmland Owner Views on Spatial Targeting for Soil Conservation and Water Quality

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Key Points:

- We examine factors that could influence the application of spatial targeting for soil conservation and water quality in the U.S. Corn Belt
- Interviewees expressed general support of spatial targeting, but expressed concern when their own fields were identified for conservation
- Future application of spatial targeting will require collaborative partnerships and adaptive incentives to overcome present barriers

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Abstract

The U.S. Corn Belt is highly productive with respect to grain and livestock commodities but often neglects to deliver other benefits such as soil stability, nutrient retention, and clean water. New precision technologies and conservation planning frameworks offer opportunities to adapt the current agricultural system to meet environmental goals along with production by strategically placing best management practices (BMPs) to target and address specific in-field resource concerns. To understand farmers' and farmland owners' willingness to participate in such targeting schemes, we conducted in-depth interviews with 18 farmers and farmland owners whose fields were targeted for soil and nutrient loss in two watersheds in central Iowa. We examined their current application of BMPs and opportunities and constraints to further adoption. We found that farmers and farmland owners often recognized the importance of producing a diverse suite of on- and off-farm environmental benefits, but lacked the context, information, certainty, and strong incentives to manage for them. Interviewees were generally receptive to using technologies to target BMPs to areas with resource concerns, but expressed concerns about applications on their own land. They specifically perceived challenges related to cost, management complexity, coordination with government programs, and loss of autonomy. For broad acceptance, a spatially targeted conservation approach would need to be paired with expanded partnerships, trusted technical service, and adaptation incentives to reduce farm-level economic tradeoffs.

1 Introduction

The U.S. Corn Belt is highly productive with respect to the production of grain and livestock based commodities. In the U.S. Corn Belt state of Iowa, the 2016 production of corn grain and soybeans resulted in a collective market value of over 13.6 billion USD (USDA National Agricultural Statistics Service, 2017). While the production of agricultural commodities provides economically tangible benefits to society, their current mode of production can negatively impact soil health, biodiversity, and water quality at local and regional levels (Power et al., 2010). These tradeoffs are complex relative to scale, timing, interactions, and impacts on society (e.g., Robertson et al., 2014). Diffuse, nonpoint source nitrate, phosphorus, and sediment originating from row-crop dominated agricultural systems have broadly endangered ecosystem health, violated safe drinking water standards, damaged local aquatic resources, restricted recreational activities, and challenged the enforcement and management of state and federal environmental quality laws (Richter et al., 1997; Ward et al., 2005; Matthaei et al., 2010; Longhurst, 2012; Brooks et al., 2016). These same pollutants are also the primary contributors to aquatic hypoxia in the Gulf of Mexico, which is a nationally recognized problem (Mississippi River Gulf of Mexico Watershed Nutrient Task Force, 2008).

With direction from the 2008 Gulf of Mexico Hypoxia Action Plan, 12 states throughout the Mississippi River Basin have been developing comprehensive, farm-oriented nutrient reduction strategies designed to achieve the minimum 45% reduction in total nitrogen and phosphorus loads in the Mississippi River (Mississippi River Gulf of Mexico Watershed Nutrient Task Force, 2008; Rabotyagov et al., 2014). The 2008 Gulf of Mexico Hypoxic Action Plan originally intended for those goals to be achieved, and the five-year average of the hypoxic zone to be less than 5,000 km^2, by 2015; the plan was amended to recognize that it may take longer than 2015 to reach that goal (Mississippi River Gulf of Mexico Watershed Nutrient Task Force, 2008). The 2012 nutrient reduction strategy for the state of Iowa is centered upon the promotion of widespread, voluntary adoption of in-field and/or edge-of-field nutrient-reducing BMPs such as nutrient-reduction management, no-till farming, cover crops, buffers, reconstructed wetlands, and/or denitrifying bioreactors (Iowa Department of Agriculture and Land Stewardship et al., 2017). The nonpoint source nutrient reduction goal for Iowa is a 41% reduction in total nitrogen and a 29% reduction in total phosphorus to fulfill the state's role for the entire Mississippi River Basin (Iowa Department of Agriculture and Land Stewardship et al., 2017).

To date, these reduction strategies largely rely upon current regional conservation funding and outreach infrastructure (i.e., USDA Natural Resource Conservation Service technical support programming) to broadly inform and incentivize the adoption of BMPs at individual farm scales. Billions of dollars have been spent over decades promoting conservation efforts throughout the U.S. Corn Belt region via a combination of cost sharing, direct rental payments, technical support, and various non-voluntary cross compliance measures; yet, government programs have thus far failed to demonstrate marked progress toward state and regional environmental quality objectives (Tomer & Locke, 2011; Osmond et al., 2012). For example, USDA conservation payments in Iowa totaled 4.97 billion USD from 1995-2016 (Environmental Working Group, 2018). Meanwhile, Iowa has long been a primary contributor to diffuse, nonpoint source nitrogen and phosphorus contributions to Gulf hypoxia (Alexander et al., 2008, Jones at al., 2018). The 2017 Gulf of Mexico hypoxic zone was the largest recorded since annual monitoring began in 1985 (LUMCOM, 2017). This lack of progress is further exacerbated by declining monetary and programmatic support for conservation in general; the 2014 federal farm bill reduced conservation funding by 4 billion USD (Lubben & Pease, 2014; Claassen, 2014).

Ultimately the reasons for the disconnect between conservation efforts and outcomes at broad scales are a complex mix of biophysical, economic and social conditions (e.g., Osmond et al., 2012). Yet, two key issues associated with historically inefficient BMP application are that they often are not spatially targeted toward critical source areas of pollutants, and there is a lack of consideration of hydrologic processes (e.g., subsurface drainage) at the watershed scale when broadly allocating conservation effort (Lemke et al., 2010; Tomer & Locke, 2011; Tomer et al., 2013). Solving these issues requires watershed management: the process of understanding and implementing BMPs at the field scale to improve water quality outcomes at the watershed scale. Implementing BMPs to improve water quality outcomes at the watershed scale requires coordinated action among the farmers and farmland owners making private land management decisions.

We conducted interviews with farmers and farmland owners who own or operate fields targeted for conservation concerns (nutrient and/or sediment loss) to understand their views on the targeted conservation approach and the co-production of agricultural commodities and environmental benefits. To do this, we used a unique watershed-scale, biophysically targeted conservation approach in two, twelve-digit hydrologic unit code (HUC-12) watersheds in central Iowa to identify fields with conservation concerns. We assessed the willingness of farmers that owned or farmed identified fields to participate in targeted conservation programming and conservation plans for soil conservation and water quality protection. Our goal was to identify factors that facilitate or constrain the application of spatially targeted conservation in the U.S. Corn Belt, particularly those that could be addressed through policy or technical service within the existing voluntary conservation paradigm.

1.1 Background and Literature Review

Historically, application of agricultural BMPs has been focused at the field level, and relatively little effort has been placed on coordinating BMP installation across property boundaries (i.e., across fields with different ownership) to achieve watershed-level outcomes. This lack of coordination has perpetuated an inefficient system where BMP placement at the field level typically neglects the aggregate watershed outcomes, or, conversely, wherein a watershed is targeted based on large-scale priorities, but field-level or sub-field level BMP applications are not prioritized or coordinated based on resource concern. Currently, application of BMPs first relies on farmers' and/or farmland owners' self-selection for voluntary adoption within singular property boundaries, typically resulting in less effective conservation outcomes at basin scales because of spatially and temporally disconnected BMPs (e.g., Secchi et al., 2008; Tomer & Locke, 2011). While attentive to parcel-level concerns, this approach been dubbed "random acts of conservation" because it usually fails to meet watershed-level goals (Knight, 2005, 137A).

Recent, relatively easy-to-use GIS-based conservation planning models have been developed to better facilitate the watershed planning required to remedy this situation (e.g., the USDA Agricultural Conservation Planning Framework; Tomer et al., 2013; Tomer et al., 2015a; Tomer et al., 2015b). Now more than ever, conservation agencies and watershed stakeholders have the capacity to link inexpensive publically available, high-resolution geospatial data (e.g., LiDAR, 1-m resolution land cover data layers, soils data layers) with knowledge of conservation effectiveness to rapidly and accurately target BMP placement to parts of the landscape where the greatest reduction in non-point source nutrient and sediment losses can be achieved. These tools factor in nutrient retention and water quality outcomes at field and basin scales (Berry et al., 2005; Tomer et al., 2013; Tomer et al., 2015). In practice, spatially targeted conservation utilizes field-to-watershed planning technologies (e.g., Geographic Information Systems, spatial data analysis, geoprocessing, and hydrologic modeling) to analyze the combined impacts of land use and management, soil properties, hydrology, drainage, nutrient cycling, and direct and indirect costs, so as to guide strategic and scale-appropriate BMP placement (Berry et al., 2005; Qiu, 2010; Tomer et al., 2013).

In addition to hydrologic and technical considerations, is the social context for and capacity of stakeholders to support targeted conservation action at appropriate scales. In the U.S. Corn Belt state of Iowa, residents have indicated an interest in the production of a broad array of environmental benefits from agriculture that complement commodities and a spatially targeted conservation policy as a method of increasing the production of environmental benefits from agricultural landscapes. For example, in 2010, 63% of Iowa voters voted for a constitutional amendment to create the Natural Resources and Outdoor Recreation Fund, which would provide a permanent and protected funding source dedicated to environmental benefits such as clean water, productive agricultural soils, and thriving wildlife habitats (Iowa Department of Natural Resources et al., 2017). In 2011 and 2012, an Iowa-wide survey noted that over 63% of respondents indicated they support directed policy for spatially targeted conservation in the state to increase the production of environmental benefits from agricultural landscapes (Arbuckle et al., 2015).

Farmers and farmland owners in Iowa have indicated they are amenable to using technology for spatially targeted conservation. Arbuckle (2013) reported that over 70% of Iowa farmers and farmland owners generally support the concept of and approaches to target conservation at watershed scales. Factors associated with support of spatially targeted conservation approaches include understanding of environmental impacts associated with agriculture, concern or experience with on-farm environmental issues and/or extreme weather events, and participation in current conservation programming (Arbuckle, 2013). Kalcic et al. (2014) interviewed farmers and farmland owners who expressed similar support for spatially targeted conservation, but identified concerns related to flexibility about application and government regulations. Using the Soil and Water Assessment Tool (SWAT) to identify suitable locations for six BMPs in west-central Indiana, Kalcic et al. (2015) interviewed 14 farmers and farmland owners to understand perceptions of conservation needs, the process of adaptive targeting, and likelihood of BMP adoption. An adaptive targeted conservation approach is an iterative process that integrates farmers' and farmland owners' input in conservation planning and implementation (Kalcic et al., 2014, Kalcic et al., 2015). Farmers and farmland owners were found to be generally amenable to the concept of spatially targeted conservation approaches, but only 35% of identified farmers and farmland owners expressed a high likelihood of adopting BMPs as per the planning process applied in the study (Kalcic et al., 2015).

Broadly examined, behavioral research exploring conservation BMP adoption has noted that farmer and farmland owner decision-making is influenced by complex individual motivations, attitudes and beliefs as well as farm characteristics and institutional factors (Prokopy et al., 2008). On-farm use of BMPs for environmental quality management requires both short and long term financial investment, while the benefits of adoption manifest in complex, often off-farm, ways. Therefore, decision making about BMP adoption is strongly influenced by economic considerations regarding on-farm benefits and costs (Liu et al., 2018). These views on economics are often balanced by farmer and farmland owner attitudes and beliefs about the compatibility and weighing of profit motivations relative to achieving stewardship goals (Chouinard et al., 2008; Reimer et al., 2012a; McGuire et al., 2013; Thompson et al., 2015; Floress et al. 2017). Decision making about BMP adoption at the individual level is often influenced by farmer/farmland owner beliefs regarding capacity to make on- and off-farm change, awareness of environmental concerns and on-farm management options, acceptance and/or availability of technical advice and financial incentives, individual farm characteristics (such as production scale, type, and geography), and perception of risk (Prokopy et al., 2008; Baumgart-Getz et al., 2012; Reimer et al., 2012; Wilson et al., 2014). Beyond individual and farm characteristics there are complex institutional and structural drivers associated with markets and policy conditions that facilitate or detract from conservation actions (Duram 2000; Blesh & Wolf, 2014).

Our research builds on the work of these prior findings and the concepts applied in Arbuckle (2013), Kalcic et al. (2014, 2015), and others. We constructed a novel, spatially targeted conservation approach in two central Iowa watersheds to identify parcels of concern for nutrient and sediment loss using a series of GIS-based models and conducted two-part interviews with the farmers and farmland owners of targeted parcels to understand their beliefs and attitudes regarding: a) researcher-developed, site-specific conservation plans regarding targeted parcels of their farms, b) cooperation with other farmers and agencies to achieve environmental quality outcomes, and c) opportunities for and constraints to spatially targeted conservation.

2 Methods

2.1 Study Area

We conducted interviews with farmers and farmland owners in the Big Creek and Squaw Creek watersheds of central Iowa regarding their perspectives on a spatially targeted conservation approach (Fig. 1). The Big Creek watershed is located in Boone, Story, and Polk counties, and extends 19,289 ha across the Des Moines Lobe landform (Prior, 1991). The watershed lies directly north of the Des Moines metropolitan area, which has approximately 500,000 residents. Approximately 82% of Big Creek watershed is in row-crop corn and soybean agriculture and 5% of the watershed is in pasture, and the primary crop rotation in the watershed is a 2-year corn-soybean rotation managed using synthetic fertilizers and pesticides. There are two confined animal feeding operations (CAFOs) in the watershed. The 306 ha Big Creek Lake, located at the southern end of the watershed, is fed by three main creeks: Turkey Creek, Big Creek, and Little Creek. The three main creeks are approximately 132 km in length (Graham, 2011). Average annual rainfall in the watershed is 838.2 mm (Graham, 2011). Big Creek Lake is listed on the U.S. EPA 303(d) list due to declining water quality, resulting from high levels of *E. coli* and high levels of algal growth caused by excess nutrients in surface waters from diffuse agricultural sources. Big Creek Lake also has an EPA-mandated Total Daily Maximum Load (TMDL) for dangerous levels of *E.coli* (Graham, 2011).

The Squaw Creek watershed is located in Jasper County, and extends 6,353 ha across the Southern Iowa Drift Plain landform (Prior, 1991). The watershed lies directly east of the Des Moines metropolitan area. Approximately 63% of Squaw Creek watershed is in row-crop corn and soybean agriculture and 14% is in pasture. Similar to Big Creek watershed, the primary crop rotation is a 2-year corn-soybean rotation managed using synthetic fertilizers and pesticides. There are two CAFOs and one animal feeding operation (AFO) in the watershed. Squaw Creek is the primary creek in the watershed and discharges into the South Skunk River. Squaw Creek is approximately 12.23 km in length (Schilling, 2000). Average annual rainfall in the watershed is 849.1 mm (Schilling, 2000). This section of the South Skunk River is listed on the U.S. EPA 303(d) list due to declining water quality from excess nutrients in surface waters from agricultural nonpoint sources and is awaiting an EPA-mandated TMDL for dangerous levels of bacteria, primarily *E.coli*. Poor water quality in the South Skunk River from upstream watersheds, such as Squaw Creek, has multiple negative effects on recreational uses and aquatic uses in the river.

These two watersheds were chosen because they represent two different major landform regions of Iowa, and the watersheds have differing biophysical characteristics (e.g., slope and percentage of highly erodible land, soil, subsurface drainage, etc.), though their land uses and general farmer/farmland owner demographics are similar. County-level data for these watersheds suggest that the range of average farm sizes are 73 to 201 hectares, and farmers/farmland owners tend to be white males with an average age of 57 years (USDA National Agriculture Statistics Service, 2012). By selecting watersheds in two different watersheds, we aimed to capture important geographic variation in farmer and farmland owner perspectives that may be related to variations in biophysical conditions of the land. We also selected these watersheds because they have been the focus of ongoing efforts related to addressing declining water quality related to drinking water, recreational, and aquatic uses (e.g., Graham, 2011). For example, in Big Creek watershed, in response to the TMDL, the county Soil and Water Conservation Districts, the Iowa Department of Land Stewardship, and the Iowa Department of Natural Resources are collaborating to provide program staff, resources, and funding to improve water quality outcomes.

2.2 A Targeted Approach to Interview Selection

The interview selection process intentionally targeted individual fields in the two study watersheds that disproportionately contributed sediment, phosphorus, and nitrogen to surface waters. Individual fields were evaluated for potential contribution of sediment, phosphorus, and nitrogen loss using three GIS-based models that were created based on the newly available Iowa LiDAR mapping data (Iowa Department of Natural Resources & Iowa LiDAR Consortium, 2007), to facilitate the identification of farm fields that were probable critical source areas – that is, areas where a field-level pollutant source (e.g., fertilizers or tillage) coincides with active hydrologic transport mechanisms (e.g., fields with artificial subsurface tile drainage; Qiu, 2010). Disproportionate refers to fields that had the potential to contribute comparatively higher amounts of nutrients and sediments relative to other fields, as predicted by the three GIS-based models. To identify areas of concentrated surface flow, we created a terrain-based stream power model to track the erosive power of flowing water (Wilson & Gallant, 2000). With a threshold of concentrated flow from at least 1.62 ha (i.e., all runoff for a patch >1.62 ha flows through a given point), this model is able to identify areas of potential ephemeral and classic gulley erosion. To identify areas prone to rill and sheet erosion, we created an erosion potential model based on slope and slope-length characteristics, accounting for complex slope geometries and the effects of concentrated erosion patterns such as rilling (Moore & Birch, 1986). Lastly, we created a model to classify subsurface drainage probability based on slope, soils, and areas with restricted surface drainage (e.g., depressional wetlands). We identified areas with a high nitrogen-leaching potential based on the output from this subsurface drainage model. None of the three models were validated with monitoring data. These methods are similar to those in the Agricultural Conservation Planning Framework (Tomer et al., 2013; Tomer et al., 2015a; Tomer et al., 2015b), which is a land use planning tool.

Sixty-five parcels were identified as having soil and water resource concerns related to sediment and nutrient loss using this spatially targeted approach. Using tract numbers from online plat maps and from the 2006 common land unit (CLU) GIS layer, 45 landowners (23 in Big Creek watershed, 22 in Squaw Creek watershed) were identified as the decision makers for these targeted parcels. A CLU is the smallest unit of land that has a permanent, contiguous boundary, a common land cover and land management, a common owner, and a common producer in agricultural land associated with USDA farm programs. Any CLU that intersected with targeted parcels in the two watersheds was selected. Farm number and tract number were extracted from the attribute table and exported to a Microsoft Excel™ file. When gaps in the data from the CLU existed, county-level assessors GIS databases were consulted for plat-level data. Identified farmland owners were contacted for participation. In cases of an owner/renter arrangement, interested farmland owners shared the names of their tenants (or contacted them on our behalf) who were contacted to solicit their participation in this study. Initial contact was made by an introductory letter, which provided a brief explanation of the study and notified farmland owners that they would receive a phone call. Phone calls were made, and nine farmers and farmland owners from the Big Creek watershed (participation rate of 39%) and nine farmers and farmland owners from the Squaw Creek watershed (participation rate of 41%) agreed to participate in the study.

2.3 Interview Protocols

Each participating farmer or farmland owner was interviewed twice between June 2012 and October 2013; each interview was semi-structured and lasted approximately 60 min.

During the first interview, we described in non-technical terms the targeting process used to identify their field(s). Interviewees provided basic information regarding their operation, current conservation challenges in their fields, on their farms, and in their watersheds, and identified current BMPs and their motivations for using these BMPs. Participants were told that the information they provided would be used by us to develop site-specific conservation plans for their farm systems with recommended BMPs in targeted fields. The first interview was structured to: 1) establish collaboration and trust between participants and ourselves as research scientists; 2) obtain farmer knowledge about conservation challenges, the success of BMPs, and interest in a spatially targeted conservation approach; and 3) record the types of information valued by farmers and farmland owners (e.g., agronomic, environmental, sociopolitical, etc.).

For each participant, our research team, guided by pre-determined goals of reducing field-level nutrient and sediment loss, created conservation plans. The spatially targeted conservation plans were designed using: 1) conservation preferences of individual farmers, as identified during the first interview; 2) specific issues of concern, as identified during the first interview; and 3) field-level biophysical data obtained from the GIS-based models. During the second interview, farmers and farmland owners were presented with these farm-specific, spatially targeted conservation plans for their fields, including maps and cost assessment for strategically integrated BMPs.

Using the field-level biophysical data obtained from the GIS-based models, BMPs were selected to specifically mitigate field-level challenges associated with soil, slope, terrain shape, and hydrology. The purpose of presenting the field-level conservation scenarios to participants was to add further applicability to interviewees' perceptions of targeted conservation plans. While farmers and farmland owners have indicated general support of targeted conservation approaches (Arbuckle 2013), interest in adoption has shown to vary when farmers and farmland owners are presented with conservation opportunities for their individual farms (e.g., Kalcic et al., 2015). Because of our specific interest in interviewees' perceptions and prior research, we provided farmers with conservation scenarios with various BMPs. The BMPs applied in conservation plans varied so as to mitigate specific concerns and to fit in a variety of operations with differing goals. More detail regarding BMPs used in conservation plans is provided in Table S1 in the supporting information. Broadly, the conservation plans were of two types: a simple scenario to capitalize on in-field practices, such as cover crops, that could be incorporated into the existing management paradigm, and/or a more advanced scenario that included BMPs that remove land from production such as prairie strips (variable width contour buffer strips planted with diverse stiff-stemmed, warm season grasses) and/or reconstructed wetlands (Fig. 2). Participants were asked about their opinions of the plan and of the specific BMPs. The second interview probed participants' opinions on managing for multiple environmental benefits, coordination and cooperation among farmers and agencies, and of the process of spatially targeted conservation within the context of their spatially targeted conservation plan. When participants were presented with tailored conservation plans, participants received a series of maps showing: (1) aerial image of the field, (2) aerial image of the field with contour overlay, (3) aerial image of the field with concentrated flow paths, (4) aerial image with conservation plan, showing location of each BMP, and when applicable, dimensions of each BMP (e.g., widths of buffers, strips, etc.). Participants did not receive quantitative information about environmental benefits (e.g., quantitative nutrient reduction from BMPs); rather, conservation plans were presented to participants as tools to generally mitigate nutrient and sediment loss from targeted fields. Participants did not receive information about incentive programs (e.g., government conservation programming) when presented with conservation plans. Interview guides used in our study are summarized in Table S2 and S3 of the supporting information.

3 Data Analysis

Interviews were audio recorded and transcribed verbatim. Transcripts were imported into the qualitative data management and analysis software, NVivo 10 (QSR, 2014). These transcripts were the primary data for this research. Qualitative data, such as the transcribed interviews in this study, are not meant to provide generalizable information across a specific population (e.g., U.S. Corn Belt farmers), yet can provide information regarding emergent topics in ways that quantitative approaches (e.g., surveys) are unable to identify or examine in-depth (Roesch-McNally et al., 2017). In the context of examining conservation behavior in agricultural or natural resource contexts, qualitative studies are often used to describe or interpret new or under researched issues, testing the boundaries of theory, in guiding policy operationalization, and in determining the exploratory dimensions of future research endeavors (particularly quantitative survey studies; Floress et al., 2018).

For this study, the lead author coded interview data using a grounded theory approach to identify emergent common, unique, and divergent themes expressed by interviewees (Corbin & Strauss, 1990). Using an iterative process, the authors developed a coding manual, which was adapted over time, narrowed, and edited to more appropriately capture emergent themes expressed by the interviewees in the context of the interview questions that were asked. We identified emergent themes of the interviews, which were categorized using the coding manual. The co-authors independently reviewed transcripts; inter-coder reliability, which refers to reproducibility of identification of emergent themes across coders, was achieved using methods wherein co-authors coded randomly selected interviews and reviewed the congruency of those codes with the codes applied by the lead author. Few new themes emerged in latter coding, providing evidence that saturation was reached for topics of interest in this research. Data saturation refers to the point where no additional issues are identified, themes begin to repeat, and further analysis becomes redundant (Kerr et al., 2010). We further illustrate the themes and provide transparency in our analysis by using direct quotations from interviewees (Prokopy, 2011). The frequencies reported in the results section are not associated with significance; the frequencies merely show common and/or divergent perceptions among interviewees. Geographic differences between interviewees in the two watersheds are integrated in with the major themes.

4 Results

The results section is organized into sections that relate to themes that emerged from the interviews (Fig. 3). Each theme is framed around common, unique, and divergent farmer beliefs that were revealed during analysis (Table 2).

4.1 General Demographics, Farm, and Conservation Characteristics of Interviewees

Seventeen of the interviewees were male, and one interviewee was female. Of the interviewees, 4 were non-farming landowners and 14 were actively farming. Interviewees expressed a strong familial history in agricultural production, and many recounted the passing of at least part of the land they are currently farming through multiple generations. Ownership of targeted parcels varied among interviewees (e.g., own, rent, crop-share). One-third of farmer interviewees owned all the land they farm, and the remaining two-thirds rented between 50% and 100% of their farmland acres. The number of acres farmed in total by interviewees ranged from 32 to 3,035 ha. The median amount of land farmed by a single interviewee was 486 ha. Targeted fields were 6-77 ha in size, and the median targeted field size was 29 ha. All interviewees grew corn and soybeans on their cropland. One-third of interviewees had livestock, predominately cattle. Cattle production ranged from approximately 10 animals to over 500 animals. Interviewees reported grazing cattle, mostly in the riparian areas along stream corridors with direct access to the waterway, and having feedlots for calving and wintering.

The majority of interviewees, especially those without livestock, did not have access to manure, and fertilized with anhydrous ammonia, generally in the fall. The majority of interviewees use chemical weed, pest, and fungal control. Interviewees with livestock were more likely to remove residue for on-farm use such as bedding and supplemental feed. The reported average yields across farms are quite variable; yields during the period when interviews were conducted were variably affected, mostly negatively, by extreme drought in 2012-2013.

All interviewees indicated that they actively managed certain fields for conservation goals and used specific BMPs on their operations. The most frequently used BMPs were grassed waterways, terraces, and tile drainage (Table 1). Other BMPs were used but not widely, these included wetlands, USDA Conservation Reserve Program (CRP) lands, tree plantings, diverse rotations, and residue management. Of the 18 interviewees, 17 interviewees reported using more than one BMP on their fields. Of the fields managed by interviewees, fields that were identified as having nutrient and/or sediment concerns by our targeting protocol did not have BMPs addressing those specific concerns.

Interviewees provided varying reasons for using BMPs on their fields. Over 70% of interviewees indicated that they had selected BMPs to address runoff and erosion on their fields, and a few interviewees specifically identified “riparian areas” as being areas of concern for these impacts. More than 70% of interviewees discussed their growing concern for the effectiveness of certain BMPs relative to recently experienced excess precipitation (prior to the 2012 drought). Of specific mention, interviewees stated that intensification of precipitation and subsequent water flow had decreased the functional capacity of tile drainage and certain BMPs, such as terraces to reduce nutrient and sediment loss.

In addition to resource concerns, one-third of interviewees noted that an intergenerational conservation ethic was fundamental to their family and their approach to farming. For example, one interviewee spoke about BMPs implemented on his century farm by his grandfather and father saying:

> …contour farming was set up to deal with erosion, particularly on some of these sloping areas. And also…another thing that was done was there's a diversion terrace that my grandfather must have put in in the 1940s or 1950s. There's a terrace here that diverts the runoff water from this farm that used to runoff here and cause a problem because once you get the water started, it becomes a continuing problem, so he diverted this into this ditch here, so this terrace was here when I was a little boy, so my grandfather had done that, or my dad might have early farming, too. These terraces were put in in the early 1980s. And I'm trying to remember, I can dig up the year, 1982, I think…that's alright. And underground outlet tiles go with that. And then these terraces were put in in 2010. My dad always had grass strips and waterways in places where water seemed to run and…my dad stopped plowing...

4.2 Concerns about Source of Excess Nutrients and Water Quality Impacts Off-farm and Downstream

Interviewees acknowledged water quality concerns such as nutrient and sediment runoff in their watersheds, but largely attributed the sources of these impairments to residential and urban areas in their watershed, and expressed frustration with urban residents not taking responsibility for water quality problems. Nearly half of interviewees indicated that more severe, concentrated, and frequent water flows are the result of increased residential areas and impervious surfaces in urban areas. They suggested these problems have been intensified by government-led efforts to channelize streams, which interviewees perceived to increase flow velocities leading to increased bank erosion. One interviewee concluded, “The pollution in the creeks, I would say 90% of [the problems] are coming off of residential properties,” emphasizing his opinion that the amount of water running off of urban impervious surfaces was the leading factor in the stream bank erosion problems, not his cattle. Another indicated, “I think the thing that bothers me the most is that they [residents of cities] want to blame all of the nitrogen and everything on the farmers, and yet, the amount of water running through here has probably more than quadrupled since I’ve owned it,” which the interviewee attributed to, “…mostly coming off of the concrete [in the city].” Moreover, noted the interviewee, “… [residents of cities] emphasize that all of this is the farmers’ problem: chemicals running off, nitrogen running off because [farmers] put too much nitrogen on their fields…”, but yet, “…they never talk about what city people are doing on their grass, and that it runs right into the storm sewers…”. Yet another interviewee remarked simply, “They want to blame the farmer [for nitrate issues].”

Less than one-third of interviewees acknowledged the role of agriculture in contributing to poor surface water quality in their watershed. One interviewee captured this common sentiment well, simply stating, “…most of the farmers that I know are doing a pretty good job [with respect to conservation].” A few interviewees did speak about general problematic outcomes from some cropping systems occurring in their watershed (e.g., farming on steep slopes, chronic loss of top soil from hillsides, farming fields prone to runoff and erosion), though rationalized, rather than place blame, when fellow producers choose not to apply certain management techniques. One interviewee explained that, “…farming is economics” and that other farmers were simply making pragmatic decisions relative to their current situation and that some producers in their watershed likely “…think they can’t afford not to do the cultivating.”

Only two interviewees spoke explicitly about downstream effects, connecting local decisions with polluted waterways and hypoxia in the Gulf of Mexico, suggesting that the majority of interviewees do not contextualize on-farm or local nutrient concerns (regardless of perceived origin) in broader, basin scales. One interviewee did state, "…I am concerned about all the chemicals that we are putting in our waterways that end up in the Mississippi causing Dead Zones." Yet, the vast majority of interviewees did not bring up concerns at this scale.

4.3 Production of Societal Benefits Requires Private Compensation

Interviewees recognized that while conservation management that benefits society may well be physically compatible with private commodity production, broadly doing so likely requires systematic and varied compensation. Primarily, interviewees expressed that farmers need a mix of subsidy-based incentives (e.g., government payments, various forms of tax abatement), market incentives (e.g., new markets such as environmental quality trading programs or expanded markets for alternative agricultural products like small grains), or simple societal recognition of some sort to broadly signal that conservation benefits are as important as commodity production and to provide immediate economic return on private conservation investment. For example, one interviewee who considered participating in the Iowa Conservation Reserve Enhancement Program (CREP), a state-federal partnership program that develops strategically located wetlands designed to remove nitrate-nitrogen from tile-drainage water in agricultural landscapes, noted that the lack of immediate economic return to the farmer often led to farmers opting out. Specifically, the interviewee noted:

> The tipping of the balance [for our participation] was, is [CREP] financially and tax-wise advantageous to me and the four sisters I represent, so those were the factors that

> we put into it, rather than worrying about the oxygen levels downstream and whether somebody in the Gulf of Mexico is going to harvest more shrimp.

Access to markets was also discussed; one farmer noted that:

> …if I had 40 acres of oats [as part of a diverse rotation], and I harvested them and put them in the bin, and I call my local elevator and want to sell it to them, they will not buy them. And it frustrates me when I want oats in my rotation…

Yet, some producers particularly in the Squaw Creek watershed were more likely to express desire for recognition from the greater public that they were trying to be stewards of their land. For example, one interviewee from the Squaw Creek watershed stated that, "…a little bit of recognition that, okay, you are doing something, you know, to keep the ground from totally going to pot."

Still, some interviewees were concerned about tradeoffs, and expressed perceptions that production and environmental outcomes were at times inherently incompatible. For example, one farmer captured this point by stating, "You want pure water? Plug every tile and you'd get it. But you'd also put every farmer up here out of business. Never happen." This "either/or" perception was supported by a number of related concerns, particularly related to who should bear the perceived costs of co-producing commodities and environmental outcomes and who benefits from that investment (cost). Interviewees repeatedly expressed they lacked information about the societal nature of conservation benefits: how an off-farm conservation benefit was defined and measured; who benefited from and experienced the off-farm environmental benefits; who was responsible for producing societal benefits, and how those individuals would be compensated; and the implications and tradeoffs of producing social benefits relative to commodity production. One interviewee shared, "Clean water is hard to get behind because we don't know what it means and who is getting it? And is it clean?" In all, interviewees recognized the importance of conservation benefits but were concerned about a lack of information, certainty, and incentives to balance production with societal conservation interests.

4.4 Wariness of Government Agencies, Regulatory Purview, and Use of Technology

Nearly 45% of interviewees had experience with United States Department of Agriculture Natural Resource Conservation Service (USDA NRCS) conservation programming, the primary federal agency charged with current government conservation programming and likely integral to the establishment of a spatially targeted conservation approach. These interviewees reflected positively on the technical expertise and helpfulness of the individual field agents they worked with. One interviewee stated, "…they're [NRCS] very helpful and the technical service is perfect, I mean our terrace layout and such, we are very happy with that." Yet, they had institutional critiques of the NRCS as an agency. Interviewees with direct NRCS experience described a strained working relationship, which they attributed to a number of factors including: bureaucratic administrative hurdles, difficult communication between the agency and farmers, lack of transparency in programming (e.g., program information, rationale of programs and or program changes), access to biophysical data that supports their participation – particularly in reference to data supporting conservation effectiveness, inefficiencies in program implementation (after a farmer signs on to participate), lack of expediency in getting BMPs implemented on farms, and finally, lack of consistency over time in terms of field assistance, payments, follow-up, monitoring and announcements regarding the timing of policy changes.

With respect to administrative hurdles and a lack of expediency, one interviewee noted that, "It takes them a couple years [to get a program going] – and to me, when I want to do it, I want to be approved the following week or whatever – and they've got all of this rigmarole to go through." One interviewee remarked on the inconsistencies of the NRCS, stating that NRCS officials, "…keep changing their minds on what they think works the best [in terms of BMPs].” and that because of this, he often feels like a “guinea pig” and, thus, that a particular practice might be unproven and possibly not in their best interests. Over 60% of interviewees perceived the NRCS to lack flexibility in prescribing programs and BMPs that could meet multiple goals (i.e., conservation and production) across time to account for uncertainties (and therefore risk) related to the climate and the market, and in the design of specific BMPs to match the heterogeneity of each individual farm – a reality that many felt could be remedied by NRCS agents taking a more active role in visiting each farm to gain on-site knowledge. Over half of interviewees directly stated that because of the aforementioned challenges, they have chosen not to work with the NRCS on various occasions. Finally, over 60% of interviewees noted a general lack of trust in government, especially the federal government, and a perception of the NRCS as a source of government overspending. One interviewee noted, “I don’t know if I’d want to get in bed with the government on a program…”, while another remarked, “Oh, the less you got to deal with the government, the better off you are…”

With respect to the technical act of spatially targeted conservation, over 65% of interviewees were comfortable with third-party entities (e.g., agency personnel, university research and extension) remotely accessing publically available information (e.g., geospatial data and satellite images) about their farms. One interviewee stated simply, “I don’t have any problem with them [NRCS, other people] looking.” Interviewees noted that the information is and has been in the public realm, and that the opportunity to use the information to help farmers, for example via precision agriculture, was promising. Nevertheless, while interviewees expressed interest in the information being used as a tool for the farmer and the NRCS to help the farmer make better agronomic and environmental decisions, there were concerns that extended beyond practical application. Approximately 55% of interviewees noted concern that such data could or would be used by federal agencies or by non-governmental entities to promote new environmental regulations and lead to a loss of independence and autonomy in decision making. One interviewee concerned about regulation stated, “If it’s to help us [the farmers] get better, then maybe it’s all right. If they’re going to use it to put restrictions on me as a landowner… um, I don’t know.” Other interviewees were more direct, stating, “…it’s our ground, not yours,” and “We have freedom to farm.” In general, interviewees in the Big Creek watershed expressed more concerned (relative to those in Squaw Creek watershed) about the government using available public information about their operations (i.e., aerial photographs, LiDAR) to make unsolicited management recommendations for their operations. It matters to interviewees how the information is used: if the information is used to prescribe BMPs in a regulatory context, interviewees were overwhelmingly opposed to its use.

4.5 Challenges to Farmer-to-Farmer Cooperation

Despite expressed dislike of regulatory, top-down interventions by government agencies, one-third of interviewees expressed a lack of optimism regarding self-organization among farmers at watershed scales and cross-boundary cooperation for off-farm environmental benefits. Interviewees noted that on a personal level, typical farmer proclivities toward “independence” and “stubbornness” are barriers to the type of cooperation likely necessary for targeted conservation. Other common barriers to cooperation included perceived individual competition over available land and commodity markets, particularly in terms of bragging rights over high yields, and the struggle over access to land and finances. One interviewee stated:

> Even now where there's tiles that cross property lines, it may be hard to get two farms, either because the operators or the owners across a property line, to agree that tile needs to be fixed because of jealousies or ownerships or financial considerations...

With respect to cooperation among farmers, interviewees in Squaw Creek watershed emphasized that local competition for farmland would be distinctly prohibitive to cooperation for conservation benefits. One interviewee used the term “cutthroat” to describe the competition for land, and noted that “…my neighbors are nearly non-existent right now cause it’s just everybody’s after every acre.” In Big Creek, the interpersonal and social context appeared to be different with many interviewees noting that they had worked with their neighbors recently to achieve greater production (i.e., installing tile, fixing drainage), but that they had never engaged to achieve environmental goals. On a more social level, interviewees noted that because rural areas are less populated and neighbors seemingly less connected, there is not a very strong rural “community” that could help promote this type of cooperation. One interviewee noted:

> …you go back 50 years, 60 years, a little further, you used to have a farmer per about 80 to 160 acres…well so, in a section of land you’d have maybe four, five, six farmers in that section. Well, they would exchange labor back and forth to get the crops in and out on a timely basis. Nowadays, that section could be farmed by one person. So, that’s one reason why you don’t have community anymore because what brought them together was the fact that they were all farmers. They all had a single goal in mind, basically. Now you might have four or five families living in that section, but none of them might be farmers. They might all be commuting to work in town. And, they don’t have the area [farming] to get together anymore.

4.6 Reaction to Farm-specific Spatially Targeted Conservation Plans

All 18 interviewees responded with neutral or negative feedback regarding the specific spatially targeted conservation plans designed for individual farms. As the field-specific conservation plans targeted fields problematic in terms of erosion, run off, drainage where BMPs were not currently employed, the plans represented additional conservation management relative to the current farm operation. While there was some pushback regarding the need for additional conservation, much of the concern was related to concerns about field management complexity, cost, and the potential for additional risk (e.g., weeds, undesirable wildlife). Other concerns also reflected previously noted issues, and involved coordination with available government agencies and programs, as well as the loss of tradition (e.g., continuing to farm in the way of grandfather, father) or decision-making autonomy.

Over 80% of interviewees noted management concerns regarding the BMP and/or row crops as the most problematic barrier to their ability to adopt suggested BMPs. Interviewees described the time demanded, both in terms of total direct time required to appropriately manage a particular practice and the timing of certain management may be difficult. This was frequently associated with BMPs that have specific spring or fall requirements, such as cover crops and prairie strips, thus potentially conflicting with the timing of planting, harvest and other crop-related activities. Other concerns related to in-field crop management such as difficulties maneuvering farm equipment around complex, narrow, and intricate BMPs (e.g., contour buffers, prairie strips). Herbicide application was deemed particularly problematic because the changing application routine not only added cost (money and time), but also added additional risk; if the BMP was planted in native grasses and the sprayer equipment could not be correctly maneuvered, the BMP (and all concomitant expenses) could be lost. One interviewee noted, "One concern … is, the equipment is so wide, that when you have point rows and overlaps…it's really nice to have things that ...work out in integral widths of a planter or a harvest unit or sprayer unit dimension…" Other management related concerns varied across certain BMPs and included: uncertainty associated with management (e.g., how to install and manage BMPs over time), the establishment of specific vegetation (e.g., establishing native grasses was a particular concern), additional labor to manage BMPs (e.g., buffers that require mowing or burning), and additional management of weeds and wildlife that the conservation practice may attract.

Specific cost concerns varied by practice, but over 50% of interviewees expressed concerns related to costs. The estimated direct costs for each spatially targeted conservation plan was a barrier as were concomitant concerns regarding unaccounted for costs associated with production management complexity. This concern stood out for cattle producers because of additional infrastructure (e.g., fencing and pump systems to exclude cattle from stream banks) and labor (e.g., labor required to rotationally graze cattle) was perceived to have high costs. Costs were also assessed relative to perceived farm-level benefits (or lack thereof). For example, one producer explained, with respect to cover crops that, “It’s all money without benefit,” because, in this case, the location of the cover crops would not permit cattle grazing of the cover crops. As a result, views on potential on-farm production benefits (or perceived lack thereof) seemed to outweigh any potential environmental benefits (on- and off-field); many of the practices were perceived to not make financial sense.

5 Discussion

We used an innovative, two-step approach to understand farmers’ and farmland owners’ beliefs about environmental benefits in the context of targeted conservation, wherein we used biophysical models to draw our sample by identifying fields with resource concerns and conducting two-stage interviews with farmers and farmland owners of those targeted fields that included a researcher-developed conservation plan. Similar to previous research (e.g., Arbuckle, 2013), interviewed farmers and farmland owners expressed general approval of a spatially targeted conservation approach. However, participants expressed concerns when their fields were being targeted for specific conservation outcomes and BMP application. Future research examining farmer and farmland owner participation in spatially targeted conservation approaches may benefit from tailored, field-specific conservation plans designed to reveal participants' specific perceptions, as opposed to broad beliefs and attitudes about spatially targeted conservation. Many of the concerns expressed by interviewees relate to previously demonstrated factors such as awareness, farmer capacity, and farm characteristics, as well as more broadly situated concerns related to agricultural markets and agricultural policy. As with other similar case studies (e.g., Kalcic et al., 2014), the discussion highlights opportunities to address some of the perceived barriers to spatially targeted conservation; nonetheless care must be taken when generalizing our findings to broader populations or to other case studies (Firestone, 1993; Polit & Beck, 2010).

Our findings suggest many farmer and farmland owners perceive that non-agricultural sources of diffuse, non-point source pollution, particularly those from urban residents, are the primary cause of surface water quality concerns. Overcoming the apparent agriculture/urban divide in farmer and farmland owner perception regarding the source of water quality impacts will be an important step for conservation planners to address. Despite evidence and scholarly consensus of the role of intensively managed, row-crop agricultural production in contributing nonpoint source pollution to surface waters (Alexander et al., 2008; David et al., 2010; Smith et al., 2015), interviewees placed the majority of the responsibility for diffuse, nonpoint source nitrogen, phosphorus, and sediment contributions to surface water on urban and residential land use. Many of the prior studies that identify the sources of diffuse, nonpoint source pollution use large-scale models (e.g., SWAT) as opposed to monitoring data across large spatial and temporal scales because such data are simply not available. The lack of measured data may influence farmer /farmland owners' perceptions on: (1) the remedial immediacy or even need in space and time to make changes in specific land use or management and/or (2) the degree of private responsibility an individual feels to ameliorate a public concern (Heinen, 1992). These perceptions and lack of awareness often manifest as motivational barriers to farmers implementing specific BMPs as per field- to farm- to watershed-scale targeted conservation plans (Gillespie et al., 2007). Awareness of environmental quality and understanding how agriculture impacts environmental quality has been shown to impact conservation practice adoption (Prokopy et al., 2008), and this situation mirrors expressions by farmers in Kalcic et al. (2014), in which interviewed farmers voiced concerns that fellow farmers do not believe their land contributes significantly to downstream problems and therefore do not identify a personal role in any spatially targeted conservation plan.

Providing farmers with additional, spatially explicit information regarding the oft hidden impacts of their land use and management can influence farmers' behavior relative to this skepticism about land management and its impacts. For example, as part of a watershed scale conservation stakeholder assessment performed for the Boone River in Central Iowa, Enloe et al. (2017) noted that farmers were more likely to remain engaged with conservation programs and to experiment with new practices when confidential field-scale personalized data, such as bioreactor or tile-line samples, stalk nitrate samples, and/or soil tests, were collected on farmers' fields and shared with farmers. Farmers found the data useful for two reasons. First, it allowed farmers to more fully understand their personal contribution to off-site water quality concerns and the potential effects of their BMPs. Second, it aided farmers in more precisely assessing their production management decisions relative to efficient nutrient use and production costs. How a soil and water conservation program is framed and the type of data that are featured in farmland owner outreach affects buy-in for spatially targeted approaches.

Interviewees responded positively to the use of technology, geospatial data, and computer models and to guidance from the NRCS to facilitate the technical components of a spatially targeted conservation approach. Applying these tools and relationships to co-identify areas of nutrient and sediment concern, viable BMPs, and on- and off-farm benefits could provide farmers and farmland owners with more information (e.g., areas with low productivity, high potential for environmental benefits) about the potential of their fields to co-produce commodities and on- and off- farm environmental benefits. Importantly, BMP planning tools such as the Agricultural Conservation Planning Framework (Tomer et al., 2013) and Right Practice, Right Place (McLellan et al., 2018) are designed to provide users with a coupled field-level and watershed-level view of biophysical risks for nutrient and sediment loss and BMP placement. These tools are presently being applied in the US Corn Belt, including locations in Iowa, Illinois, Minnesota, and Ohio, and could be useful in other agricultural regions, such as the Chesapeake Bay area on the East Coast of the United States. With technical guidance and on-farm site visits from resource managers (e.g., NRCS officials, land managers, non-profit advisors), this approach could provide educational information to farmers and farmland owners about the importance of their farm in co-producing on- and off-farm environmental benefits and provide innovative opportunities for cooperation at watershed levels.

The farmers/farmland owners in our study were variously using BMPs in their farm systems, but largely in the context of achieving private benefits such as maintaining soil health by minimizing soil erosion, and maximizing water management designed to enhance crop production. Off-farm benefits seemed to be of secondary consideration in the use of BMPs; for example, many practices that take land out of production or have somewhat limited crop production related benefits (e.g., wetlands, CRP) were the least utilized (Table 1). This perception reflects challenges farmers face in reconciling profit maximization with stewardship goals.

U.S. Corn Belt state nutrient reduction strategies (e.g., Illinois, Iowa, Missouri) explicitly call for a targeted approach to conservation planning and implementation to achieve surface water quality improvements (Missouri Department of Natural Resources, 2014; Illinois et al., 2015; Iowa Department of Agriculture and Land Stewardship et al., 2017). Our study, as well as others (e.g., Roesch-McNally et al. 2017; Wilson et al., 2014), suggests that a state's nutrient reduction strategy implementation programming and promotion of certain BMPs, particularly in the context of spatial targeting, would likely benefit by explicitly addressing the potential production-side benefits of BMP adoption in salient metrics such as income or cost savings along with biophysical outcomes. This has been part of the USDA NRCS's strategy with its Soil Health Initiative. Starting in 2012, this initiative has encouraged farmers and farmland owners to maintain and enhance individual farm economics via healthy and productive soil resources, through the use of conservation BMPs. Supporting data such as the impact of increased soil organic matter or stable soil aggregate structure associated with the long-term use of cover crops remain scant, however, as the private, field-level economic effects of many BMPs are often difficult to quantify due to the frequently complex, long-term, biophysically emergent nature of benefits.

Nonetheless, research and data are becoming available to inform decision making on the private economic or production benefits associated with BMPs (Plastina & Liu, 2016). A potential challenge to this approach is that incentives for conservation that focus on private benefits (such as maintaining crop yields) have often been viewed as being too weak to broadly encourage use at watershed scales. For example, compensating expenses for yield loss due to erosion is usually a small fraction of overall production costs and is therefore discounted in context (e.g., Crosson, 1986). Furthermore, the total private cost of factors that impact downstream water quality is typically considerably less than the total cost to the public due to water quality impairments. Thus, in the aggregate, to focus on the weakest incentive that tackles the lowest cost perspective may be counterproductive to the public goals (and tax payer expense) of conservation policy (Crosson, 1986). Nevertheless, due to recent advances in the availability of site-level data and enhanced decision support, the nature of the private benefit as incentive may be changing.

More so than ever before, farmers can more precisely manage for field-level profit (as opposed to maximizing yield) and this profit management can be highly compatible with conservation management and BMP placement (Muth, 2014; Brandes et al., 2016). That is, when possible, incorporating BMPs into consistently low-yielding portions of fields can often increase overall field profitability (Brandes et al., 2016). Thus, framing the use of BMPs as guided by spatial targeting around personalized, precision profit management, might contextualize spatial targeting in ways that mitigate the perceived benefit/cost imbalances articulated by farmers and farmland owners we interviewed and help farmers to reconcile goals of profitability and stewardship.

Relative to the policy concerns mentioned above regarding incentives for private gain, an important finding was that interviewees desired direct and indirect incentives to signal that off-farm environmental benefits are as important as commodity production, and that they provide immediate economic return. Current government programming does provide direct incentives for many BMPs, but there are few alternative incentives that focus on new environmental outcome markets for farmers in Iowa and throughout the U.S. Corn Belt region. Still, innovative approaches such as water quality trading programs (Selman et al., 2009), payment for ecosystem service approaches (Wunder et al., 2008), and banking programs (Robertson, 2006) have become increasingly common elsewhere in the U.S. and globally (e.g., Greenhalgh & Selman, 2012; Grima et al., 2016). These incentive programs provide market-based approaches to encourage the production of off-farm benefits, and have the potential to financially incentivize the production of what would otherwise be non-market, off-farm benefits by linking the producers of environmental benefits with users in a market-based exchange.

The non-market nature of public benefits such as water quality is a classic economic policy conundrum and one that has confounded the development of effective voluntary conservation policy for decades (Wolf, 1979). Research has shown, however, that farmers in the U.S. have been reluctant to participate in many of these approaches, for reasons that are similar to issues highlighted in our study: specifically, due to lack of willingness to work with the government and desire for innovative and trusted third-party program administrators (Breetz et al. 2005). There are limitations to market-based incentive programs, primarily challenges related to the characteristics of off-farm environmental benefits (e.g., public goods that are non-rival and non-excludable) and the monitoring and measurement of off-farm benefits over time and space to ensure the conditionality of markets (Kroger & Casey, 2007; Farley & Costanza, 2010; Ribaudo & Gottlieb, 2011).

Still, these approaches may be promising in concept and practice. Environmental markets are best centered on explicit performance-based outcomes at appropriate scales as opposed to implicit outcomes tied to individual actions (e.g., current conservation programs such as EQIP and CRP help pay for conservation practices that implicitly provide environmental benefits); thus, counteracting the efficiency without optimality dilemma of public environmental policy (Secchi et al. 2008). Such market or quasi-market (e.g., nutrient trading) approaches shift the perspectives of participants by assigning property rights to outcomes that are "caused" by specific actions such that market exchange is possible among willing sellers and buyers (Kroger & Casey, 2007). Environmental markets based on performance outcomes will benefit from the same high-resolution data and tools used to spatially target conservation so that sellers and actions can more readily be identified (targeted fields, use of appropriate BMPs), market outcomes can be more fully characterized and measured (improved water quality at scale and over time), and environmental quality beneficiaries/ buyers can better weight their willingness to pay (Engel et al. 2008; Wortmann et al., 2008). It remains to be seen how these new spatial technologies and publicly available data will impact the emergence of environmental markets and supporting policy, but safe to suggest that natural resource agencies and policy makers are more informed than ever before to foster such outcomes (Secchi et al., 2008).

Beyond the framing of personalized, spatially targeted conservation programming, farmers/farmland owners appear to have concerns about the current institutional structure of water quality management and guidance. Current conservation programming, under the direction of the USDA NRCS was perceived as cumbersome, inflexible, and overly bureaucratic by interviewees. This is concerning in the context of a spatially targeted conservation approach because of the inherent and expanded complexity of targeted conservation programming from a logistical standpoint (i.e., identification of fields with nutrient and sediment concerns, watershed-level and field-level conservation plans, contact with farmers and farm landowners of targeted fields, strategic implementation, etc.). Other agencies, non-governmental organizations, or institutions may be able to work in partnership with the NRCS to more effectively coordinate a spatially targeted conservation program. Research by Prokopy et al. (2014) suggests farmers are increasingly looking to agribusiness for advice about agricultural practices and strategies. Innovative partnerships between a variety of organizations (e.g., agribusiness/conservation non-profit/government agency) may be effective at providing greater transparency, more diverse management advice, and improved on-site support and monitoring for conservation programming. These challenges warrant further exploration of innovative incentives and partnerships, including but not limited to market-based programs, to facilitate the co-production of on- and off-farm benefits in working landscapes like the U.S. Corn Belt.

6 Conclusions

This qualitative study of central Iowa farmers' and farmland owners' attitudes, beliefs, and behaviors about conservation and managing for on- and off-farm environmental benefits provides insights for the development of spatially targeted conservation approaches. We found that farmers and farmland owners often recognized the importance of producing a diverse suite of on- and off-farm environmental benefits, but lacked the context, information, certainty, and incentives to manage for on- and off-farm benefits. Farmers and farmland owners perceived that non-agricultural sources of diffuse, nonpoint source pollution are the primary contributors to water quality issues, which suggests a need to develop and implement a large-scale monitoring network from which data could be collected, evaluated, and shared with stakeholders. Farmers and farmland owners also perceived challenges related to the cost, additional management complexity and potential problems, coordination with government programs, and loss of autonomy. Farmers and farmland owners in this study highlight some common challenges that policy and engagement programs may find useful in navigating a way toward more widespread-targeted approaches to conservation. For broad acceptance, a spatially targeted conservation approach would need to collaboratively develop partnerships to overcome administrative hurdles, including lack of expediency and flexibility, and general government distrust associated with current conservation programming. Adaptive incentives, which reduce farm-level economic tradeoffs, could help meet individual needs and connect producers of environmental benefits to their users.

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References

Alexander, R.B., Smith, R.A., Schwartz, G.E., Boyer, E.W., Nolan, J.V., & Brakebill, J.W. (2008). Differences in phosphorus and nitrogen delivery to the Gulf of Mexico from the Mississippi River Basin. *Environmental Science Technolog*y, **42**(3), 822-830. https://doi.org/ 10.1021/es0716103

Arbuckle, J. (2013). Farmer attitudes toward proactive targeting of agricultural conservation programs. *Society & Natural Resources*, **26**(6), 625-641. https://doi.org/10.1080/08941920.2012.671450

Arbuckle, J., Tyndall, J., & Sorenson, E. (2015). *Iowans' perspectives on targeted approaches for multiple-benefit agriculture.* (Sociology Technical Report 1038). Ames, IA: Iowa State University.

Baumgart-Getz, A., Prokopy L.S., & Floress, K. (2012) Why farmers adopt best management practice in the United States: A meta-analysis of the adoption literature. *Journal of Environmental Management*, **96**(1), 17-25. https://doi.org/10.1016/j.jenvman.2011.10.006

Berry, J. K., Delgado, J.A., Pierce, F.J., & Kholsla, R. (2005). Applying spatial analysis for precision conservation across the landscape. *Journal of Soil and Water Conservation,* **60**(6), 363–370.

Blesh, J., & Wolf, S.A. (2014). Transitions to agroecological farming systems in the Mississippi river basin: Toward an integrated socioecological analysis. *Agriculture and Human Values*, **31**(4), 621–635. https://doi.org/10.1007/s10460-014-9517-3

Brandes, E., McNunn, G.S., Schulte, L.A., Bonner, I.J., Muth, D.J., Babcock, B.A., Sharma, B., & Heaton, E.A. (2016). Subfield profitability analysis reveals an economic case for cropland diversification. *Environmental Research Letters*, **11**(1), 1-13. https://doi.org/10.1088/1748-9326/11/1/014009

Breetz, H.L., Fisher-Vanden, K., Jacobs, H., & Schary, C. (2005). Trust and communication: Mechanisms for increasing farmers' participation in water quality trading. *Land Economics*, **81**(2), 170-190. https://doi.org/10.3368/le.81.2.170

Brooks, B.W., Lazorchak, J.M., Howard, M.D.A., Johnson, M.V., Morton, S.L., Perkins, D.A.K., Reavie, E.D., Scott, G.I., Smith, S.A., & Steevens, J.A. (2016). Are harmful algal blooms becoming the greatest inland water quality threat to public health and aquatic ecosystems? *Environmental Toxicity and Chemistry*, **35**(1), 6-13. https://doi.org/10.1002/etc.3220

Chouinard, H., Paterson, T., Wandschneider, P., & Ohler, A. (2008). Will farmers trade profits for stewardship? Heterogeneous motivations for farm practice selection. *Land Economics*, **84**(1), 66-82. https://doi.org/10.3368/le.84.1.66

Claassen, R. (2014). 2014 farm act continues most previous trends in conservation. *Amber Waves Magazine.* Retrieved from: https://www.ers.usda.gov/amber-waves/2014/may/2014-farm-act-continues-most-previous-trends-in-conservation/

Corbin, J., & Strauss, A. (1990). *Basics of Qualitative Research*. Newbury Park, CA: Sage Publications.

Crosson, P. (1986). Soil conservation: It's not the farmers who are most affected by erosion. *Choices*, **1**(1): 33-38.

David, M.B., Drinkwater, L.E., & McIsaac, G.F. (2010). Sources of nitrate yields in the Mississippi River Basin. *Journal of Environmental Quality*, **39**(5), 1657-1667. https://doi.org/10.2134/jeq2010.0115

Duram, L.A. (2000). Agents' perceptions of structure: How Illinois organic farmers view political, economic, social, and ecological factors. *Agriculture and Human Values*, **17**(1), 35-48. https://doi.org/10.1023/A:1007632810301

Engel, S., Pagiola, S., & Wunder, S. (2008). Designing payments for environmental services in theory and practice: An overview of the issues. *Ecological economics*, ***65***(4), 663-674. https://doi.org/10.1016/j.ecolecon.2008.03.011

Enloe, S.K., Schulte, L.A., & Tyndall, J.C. (2017). Public-private partnerships working beyond scale challenges toward water quality improvements from private lands. *Environmental Management*, **60**(4), 574-587. https://doi.org/10.1007/s00267-017-0905-5

Environmental Working Group. (2018). *Farm Subsidy Information*. Retrieved from https://farm.ewg.org/region.php?fips=19000

Farley, J., & Costanza, R. (2010). Payments for ecosystem services: From local to global. *Ecological Economics*, **69**(11), 2060-2068. https://doi.org/10.1016/j.ecolecon.2010.06.010

Firestone, W.A. (1993). Alternative arguments for generalizing from data as applied to qualitative research. *Educational Researcher*, **22**(4), 16-23.

Floress, K., Garcia de Jalon, S., Church, S.P., Babin, N., Ulrich-Schad, J.D., & Prokopy, L.S. (2017). Toward a theory of farmer conservation attitudes: Dual interests and willingness to take action to protect water quality. *Journal of Environmental Psychology*, **53**, 73-80. https://doi.org/10.1016/j.jenvp.2017.06.009

Floress, K., Reimer, A., Thompson, A., Burbach, M., Knutson, C., Prokopy, L., Ribaudo, M., & Ulrich-Schad, J. (2018). Measuring farmer conservation behaviors: Challenges and best practices. *Land Use Policy*, **70**, 414-418. https://doi.org/10.1016/j.landusepol.2017.11.030

Gillespie, J., Kim, S., & Paudel, K. (2007). Why don't producers adopt best management practices? An analysis of the beef cattle industry. *Agricultural Economics*, **36**(1), 89-102. https://doi.org/10.1111/j.1574-0862.2007.00179.x

Graham, W. (2011). *Water Quality Improvement Plan for Big Creek Lake Polk County, Iowa: Total Maximum Daily Load For Pathogen Indicators (E. coli).* Des Moines, IA: Iowa Department of Natural Resources Watershed Improvement Section.

Greenhalgh, S. & Selman, M. (2012). Comparing water quality trading programs: What lessons are there to learn? *Journal of Regional Analysis and Policy*, **42**(2), 104-125.

Grima, N., Singh, S.J., Smetchka, B., Ringhofer, L. (2016). Payment for ecosystem services in Latin America: Analysing the performance of 40 case studies. *Ecosystem Services*, **17**, 24-32. https://doi.org/10/1016/j.ecoser.2015.11.010

Heinen, J.T. (1992). Human behavioural ecology and environmental conservation. *Environmental Conservation*, **19**(2), 105-116. https://doi.org/10.1017/S0376892900030575

Illinois, Illinois Department of Agriculture, Illinois Environmental Protection Agency. (2015). *Illinois Nutrient Reduction Strategy.* Retrieved from http://www.epa.illinois.gov/Assets/iepa/water-quality/watershed-management/nlrs/nlrs-final-revised-083115.pdf.

Iowa Department of Agriculture and Land Stewardship, Iowa Department of Natural Resources,
& Iowa State University College of Agriculture and Life Sciences. (2017). *Iowa nutrient reduction strategy. A science and technology-based framework to assess and reduce nutrients to Iowa waters and the Gulf of Mexico.* Retrieved from http://www.nutrientstrategy.iastate.edu/sites/default/files/documents/2%202017%20INRS%20Section%202_Science%20Assessment.pdf.

Iowa Department of Natural Resources, Iowa Department of Agriculture and Land Stewardship,
& Iowa Department of Transportation. Des Moines, Iowa. (2017). *Natural Resource and Outdoor Recreation Trust Fund Report*. Retrieved from https://www.legis.iowa.gov/docs/publications/DF/851390.pdf

Iowa Department of Natural Resources & Iowa LiDAR Consortium. (2007). The Iowa LiDAR
Project. Retrieved from http://www.geotree.uni.edu/lidar/

Jones, C.S., Nielsen, J.K., Schilling, K.E., & Weber, L.J. (2018). Iowa stream nitrate and the Gulf of Mexico. *Plos One*, 13(4), e0195930. https://doi.org/10.1371/journal.pone.0195930

Kalcic, M., Prokopy, L., Frankenberger, J., & Chaubey, I. (2014). An in-depth examination of
farmers' perceptions of targeting conservation practices. *Environmental Management*, **54**(4), 795-813. https://doi.org/10.1007/s00267-014-0342-7

Kalcic, M., Frankenberger, J., Chaubey, I., Prokopy, L., & Bowling, L. (2015). Adaptive targeting: Engaging farmers to improve targeting and adoption of agricultural conservation practices. *Journal of the American Water Resources Association*, **51**(4), 973-991. https://doi.org/10.1111/1752-1688.12336

Kerr, C., Nixon, A., & Wild, D. (2010). Assessing and demonstrating data saturation in qualitative inquiry supporting patient-reported outcomes research. *Expert Review of Pharmacoeconomics & Outcomes Research*, **10**(3), 269-281. https://doi.org/10.1586/erp.10.30

Knight, B.I. (2005). Precision Conservation. *Journal of Soil and Water Conservation*, **60**(6), 137A.

Kroeger, T., & Casey, F. (2007). An assessment of market-based approaches to providing ecosystem services on agricultural lands. *Ecological Economics*, **64**(2), 321-332. https://doi.org/10.1016/j.ecolecon.2007.07.021

Lemke, A.M., Lindenbaum, T.T., Perry, W.L., Herbert, M.E., Tear, T.H., & Herket, J.R. (2010).
Effects of outreach on the awareness and adoption of conservation practices by farmers in two agricultural watersheds of the Mackinaw River, Illinois. *Journal of Soil and Water Conservation,* **65**(5), 304-315. https://doi.org/10.2489/jswc.65.5.304

Longhurst, C. (2012). Where is the point? Water quality trading's inability to deal with nonpoint
source agricultural pollution. *Drake Journal of Agricultural Law*, **17**(1), 175-209.

Lubben, B., & Pease, J. (2014). Conservation and the Agricultural Act of 2014. *Choices*. **29**(2),
1-8.

Louisiana Marine Consortium (LUMCOM). 2017. 2017 Shelfwide Cruise: July 24-31. Retrieved
from https://gulfhypoxia.net/research/shelfwide-cruise/?y=2017&p=press_release

Liu, T., Bruins, R. J., & Heberling, M. T. (2018). Factors Influencing Farmers' Adoption of Best Management Practices: A Review and Synthesis. *Sustainability*, **10**(2), 432. https://doi.org/10.3390/su10020432

Matthaei, C.D., Piggot, J.J., & Townsend, C.R. (2010). Multiple stressors in agricultural streams: interactions among sediment addition, nutrient enrichment and water abstraction. *Journal of Applied Ecology*, **47**(3), 639-649. https://doi.org/10.1111/j.1365-2664.2010.01809.x

McGuire, J., Wright Morton, L., & Cast, A.D. (2013). Reconstructing the good farmer identity: Shifts in farmer identities and farm management practices to improve water quality. *Agriculture and Human Values*, **30**(1), 57-69. https://doi.org/10.1007/s10460-012-9381-y

McLellan, E.L., Schilling, K.E., Wolter, C.F., Tomer, M.D., Porter, S.A., Magner, J.A., Smith D.R., & Prokopy, L. (2018). Right practice, right place: A conservation planning toolbox for meeting water quality goals in the Corn Belt. *Journal of Soil and Water Conservation*, **73**(2), 29A-34A.

Mississippi River Gulf of Mexico Watershed Nutrient Task Force. (2008). *Gulf Hypoxia Action Plan 2008.* Retrieved from: https://www.epa.gov/sites/production/files/2015-03/documents/2008_8_28_msbasin_ghap2008_update082608.pdf

Missouri Department of Natural Resources. (2014). Missouri's Nutrient Loss Reduction Strategy: A collaborative strategy to bring practical nutrient reductions to Missouri's waters. Retrieved from https://dnr.mo.gov/env/wpp/mnrsc/docs/nlrs-strategy-2014.pdf.

Muth, D. (2014). Profitability versus environmental performance: Are they competing? *Journal of Soil and Water Conservation*, **69**(6), 203A-206A. https://doi.org/10.2489/jswc.69.6.203A

Osmond, D., Meals, D., Hoag, D., Arabi, M., Luloff, A., Jennings, G., McFarland, M., Spooner, J., Sharpley, A., & Line, D. (2012). Improving conservation practices programming to protect water quality in agricultural watersheds: Lessons learned from the National Institute of Food and Agriculture–Conservation Effects Assessment Project. *Journal of Soil and Water Conservation*, **67**(5), 122A-127A. https://doi.org/10.2489/jswc.67.5.122A

Plastina, A., & Liu, F. (2016, July). *Comprehensive partial budgets for cover crops in Midwest row-crop agriculture*. Poster session at the annual meeting of the Agriculture and Applied Economics Association, Boston, MA.

Polit, D.F., & Beck, C.T. (2010). Generalization in quantitative and qualitative research: Myths and strategies. *International Journal of Nursing*, **47**(11), 1451-1458. https://doi.org/10.1016/j.ijnurstu.2010.06.004

Power, A.G. (2010). Ecosystem services and agriculture: tradeoffs and synergies. *Philosophical Transactions of the Royal Society B: Biological Sciences*, **365**, 2959-2971. https://doi.org/10.1098/rstb2010.0143

Prior, J. (1991). Landforms of Iowa. Iowa City, USA: University of Iowa Press.
Prokopy, L.S., Floress, K., Klotthor-Weinkauf, D., & Baumgart-Getz, A. (2008). Determinants of agricultural best practice adoption: Evidence from the literature. *Journal of Soil and Water Conservation*, **63**(5), 300-311. https://doi.org/10.2489/jswc.63.5.300
Prokopy, L.S. (2011). Agriculture human dimensions research: The role of qualitative research methods. *Journal of Soil and Water Conservation*, **66**(1), 9A-12A. https://doi.org/10.2489/jswc.66.1.9A
Prokopy, L.S., Towery, D., & Babin, N. (2014). *Adoption of agricultural practices: Insights from research and practice.* (Purdue Extension Bulletin). West Lafayette, IN: Purdue University.
Qiu, Z. (2010). Variable Source Pollution: Turning science into action to manage and protect critical source areas in landscapes. *Journal of Soil and Water Conservation*, **65**(6), 137A-141A. https://doi.org/ 10.2489/jswc.65.6.137A
QSR. (2014). NVivo 10. QSR International Pty Ltd. Doncaster, Victoria, Australia.
Rabotyagov, S.S., Kling, C.L., Gassman, P.W., Rabalais, N.N., & Turner, R.E. (2014). The economics of dead zones: Causes, impacts, policy challenges, and a model of the Gulf of Mexico hypoxic zone. *Review of Environmental Economics and Policy,* **8**(1), 58-79. https://doi.org/10.1093/reep/ret024
Reimer, A.P., Thompson, A.W., & Prokopy, L.S. (2012). The multi-dimension nature of environmental attitudes among farmers in Indiana: Implications for conservation adoption. *Agriculture and Human Values*, **29**(1), 29-40. https://doi.org/10.1007/s10460-011-9308-z
Reimer, A.P., Klotthor Weinkauf, D., & Prokopy, L.S. (2012a). The influence of perceptions of practice characteristics: An examination of agricultural best management practice adoption in two Indiana watersheds. *Journal of Rural Studies*, **28**(1), 118-128. https://doi.org/10.1016/j.jrurstud.2011.09.005
Ribaudo, M.O., & Gottlieb, J. (2011). Point-nonpoint trading: Can it work? *Journal of the American Water Resources Association*, **47**(1), 5-14. https://doi.org/10.1111/j.1752-1688.2010.00454.x
Richter, B.D., Braun, D.P., Mendelson, M.A., & Master, L.L. (1997). Threats to imperiled freshwater fauna. *Conservation Biology*, **11**(5), 1081-1093. https://doi.org/10.1046/j.1523-1739.1997.96236.x
Robertson, M.M. (2006). Emerging ecosystem service markets: Trends in a decade of entrepreneurial wetland banking. *Frontiers in Ecology and Environment,* **4**(6), 297-302. https://doi.org/10.1890/1540-9295(2006)4[297:EESMTI]2.0.CO;2
Robertson, P.G., Gross, K.L., Hamilton, S.K., Landis, D.A., Schmidt, T.M., Snapp, S S., & Swinton, S. M. (2014). Farming for ecosystem services: An ecological approach to production agriculture. *BioScience,* **64**(5), 404-415. https://doi.org/10.1093/biosci/biu037
Roesch-McNally, G.E., Basche, A.D., Arbuckle, J.G., Tyndall, J.C., Miguez, F.E., Bowman, T., & Clay, R. (2017). The trouble with cover crops: Farmers' experiences with overcoming barriers to adoption. *Renewable agriculture and food systems,* (March 2017), 1-12. https://doi.org/10.1017/S1742170517000096
Schilling, K. (2000). Patterns of discharge and suspended sediment transport in the Walnut and

Squaw Creek watersheds, Jasper County, Iowa: Water Years 1996-1998. *Geological Survey Bureau Technical Information Series 42*. Retrieved from https://ir.uiowa.edu/cgi/viewcontent.cgi?article=1041&context=igs_tis

Secchi, S., Tyndall, J., Schulte, L.A., & Asbjornsen, H. (2008). High crop prices and conservation – Raising the stakes of conservation. *Journal of Soil and Water Conservation,* **63**(3), 68A-73A. https://doi.org/10.2489/jswc.63.3.68A

Selman, M., Greenhalgh, S., Branosky, E., Jones, C., & Guiling, J. (2009). Water Quality Trading Programs: An International Overview. *World Resources Institute Issue Brief.* Retrieved from: http://www.wri.org/sites/default/files/pdf/water_trading_quality_programs_international_overview.pdf

Smith, D.R., King, K.W., Johnson, L., Francesconi, W., Richards, P., Baker, D., & Sharpley, A.N. (2015). Surface runoff and tile drainage transport of phosphorus in the Midwestern United States. *Journal of Environmental Quality,* **44**(2), 495-502. https://doi.org/10.2134/jeq2014.04.0176

Thompson, A.W., Reimer, A., & Prokopy, L.S. (2015). Farmers' views of the environment: The influence of competing attitude frames on landscape conservation efforts. *Agriculture and Human Values*, **32**(3), 385-399. https://doi.org/10.1007/s10460-014-9555-x

Tomer, M.D., & Locke, M.A. (2011). The challenge of documenting water quality benefits of conservation practices: a review of USDA-ARS's conservation effects assessment project watershed studies. *Water Science and Technology,* **64**(1), 300-310. https://doi.org/10.2166/wst.2011.555

Tomer, M., Porter, S.A., James, D.E., Boomer, K.M.B., Kostel, J.A., & McLellan, E. (2013). Combining precision conservation technologies into a flexible framework to facilitate agricultural watershed planning. *Journal of Soil and Water Conservation,* **68**(5), 113A-120A. https://doi.org/10.2489/jswc.68.5.113A

Tomer, M.D., Porter, S.A., Boomer, K.M.B., James, D.E., Kostel, J.A., Helmers, M.J., Isenhart, T.M., & McLellan, E. (2015a). Agricultural conservation planning framework: 1. Developing multipractice watershed planning scenarios and assessing nutrient reduction potential. *Journal of Environmental Quality,* **44**(3), 754-767. https://doi.org/10.2134/jeq2014.09.0386

Tomer, M.D., Boomer, K.M.B., Porter, S.A., Gelder, B.K., James, D.E., & McLellan, E. (2015b). Agricultural conservation planning framework: 2. Classification of riparian buffer design types with application to assess and map stream corridors. *Journal of Environmental Quality,* **44**(3), 768-779. https://doi.org/10.2134/jeq2014.09.0387

Tyndall, J., & Bowman, T. (2016). *Iowa Nutrient Reduction Strategy Best Management Practice Cost Overview Series.* Ames, IA: Department of Natural Resource Ecology & Management, Iowa State University.

Tyndall, J., & Roesch, G.E. (2014). Agricultural water quality BMPs: A standardized approach to financial analysis. Journal of Extension, **52**(3), 1-12.

USDA National Agriculture Statistics Service. (2017). *2017 State Agriculture Overview*. Retrieved from: https://www.nass.usda.gov/Quick_Stats/Ag_Overview/stateOverview.php?state=IOWA

USDA National Agricultural Statistics Service. (2012). *2012 Census of Agriculture: Iowa State* *and County Data.* Retrieved from https://www.agcensus.usda.gov/Publications/2012/Full_Report/Volume_1,_Chapter_2_County_Level/

USDA National Agricultural Statistics Service Cropland Data Layer. (2013). *Published crop-specific data layer.* Retrieved from: https://nassgeodata.gmu.edu/CropScape/

Ward, M.H., deKok, T.M., Levallois, P., Brender, J., Nolan, B.T., & VanDerslice, J. (2005). Workgroup Report: Drinking-water nitrate and health – Recent findings and research needs. *Environmental Health Perspectives*, **113**(11), 1607-1614. https://doi.org/10.1289/ehp.8043

Wilson, J.P., & Gallant., J.C. (2000). Terrain Analysis: Principles and Applications. New York, NY: John Wiley & Sons.

Wilson, R.S., Howard, G., & Burnett, E.A. (2014). Improving nutrient management practices in agriculture: The role of risk-based beliefs in understanding farmers' attitudes toward taking additional action. *Water Resources Research*, **50**(8), 6735-6746. https://doi.org/10.1002/2013WR015200

Wolf, C., Jr. (1979). A Theory of nonmarket failure: Framework for implementation analysis. *Journal of Law and Economics*, **22**(1), 107-139.

Wortmann, C. S., Helmers, M., Gelder, B., Morton, L. W., Devlin, D., Barden, C., Anderson, S., Broz, R., Franti, T., Regassa, T., Shea, P., Tomer, M.D., Frees, L., Griffith, D., & Frizzell, D. (2008). *Targeting of watershed management: Practices for water quality protection.* Lincoln, NE: Extension Publications, Heartland Regional Water Coordination Initiative.

Wunder, S., Engel, S., & Pagiola, S. (2008). Taking stock: A comparative analysis of payments for environmental services programs in developed and developing countries. *Ecological Economics,* **65**(4), 834-852. https://doi.org /10.1016/j.ecolecon.2008.03.010

Table 1. *Conservation BMPs used by interviewees*. The numbers in the column on the right indicate the number of farmers/farmland owners who discussed using that practice on their farm at the time of their interview.

Best Management Practices	**Number of interviewees**
Grassed waterways	9
Terraces	6
Tile drainage	6
Conservation tillage and/or no-till soil management	5
Buffers, riparian and edge-of-field	3
Rotational grazing	3
Cover Crops	3
Residue management	2
Filter strips	2
Agroforestry	1
Conservation Reserve Program	1
Contour planting	1
Diverse crop rotations	1
Wetlands	1

Table 2. *Themes and representative quotes from interviewees.* The five central themes, key associated themes, and select representative quotations from in-depth interviews and qualitative analysis of interview data.

Central Theme	**Key Associated Themes, (% of interviewees mentioning theme)**	**Representative Quotes**
On- and off-farm nutrient and resource concerns	• Concern about more severe concentrated and frequent water flows from increased impervious surfaces in residential/urban areas (50%) • Acknowledgement of the role of agriculture in contributing to poor surface water quality in watershed (33%) • Concern for downstream or regional effects associated with increased flow or poor surface water quality (11%)	• "The pollution in the creeks, I would say 90% of [the problems] are coming off of residential properties." • "They want to blame the farmer [for nitrate issues]." • "…I am concerned about all the chemicals that we are putting in our waterways that end up in the Mississippi causing Dead Zones."
Compensation for societal benefits (i.e., incentives and recognition)	• Recognition of physical compatibility of coproducing commodities and environmental benefits, but doing so likely requires systematic and varied compensation (50%) • Perception that coproduction of commodities and environmental benefits are inherently incompatible (50%)	• "The tipping of the balance [for our participation] was, is [CREP] financially and tax-wise advantageous to me and the four sisters I represent…" • "You want pure water? Plug every tile and you'd get it. But you'd also put every farmer up here out of business. Never happen."
Role of agencies, policy, and technology	• Experience working with USDA NRCS on conservation programming (45%) • Perception that USDA NRCS lacks flexibility in prescribing conservation programming (60%) • Comfortable with third-party entities remotely accessing publically available information about their farms (65%) • Concern that remotely accessed, publically available information could be used to promote environmental regulations (55%)	• "…they're [NRCS] very helpful and the technical service is perfect, I mean our terrace layout and such, we are very happy with that." • "It takes them a couple years [to get a program going] – and to me, when I want to do it, I want to be approved the following week or whatever – and they've got all of this rigmarole to go through." • "If it's to help us [the farmers] get better, then maybe it's all right. If they're going to use it to put restrictions on me as a landowner… um, I don't know."
Alignment with current farming system and practices	• Neutral or negative feedback about specific spatially targeted conservation plan (100%) • Concerns about management regarding the BMP and/or row crops (80%) • Concerns about costs regarding BMP implementation (50%)	• "One concern … is, the equipment is so wide, that when you have point rows and overlaps…it's really nice to have things that ...work out in integral widths of a planter or a harvest unit or sprayer unit dimension…." • "It's all money without benefit."
Farmer cooperation and rural communities	• Perception of farmers' ability to self-organize to achieve off-farm environmental benefits (33%)	• "…my neighbors are nearly non-existent right now cause it's just everybody's after every acre."

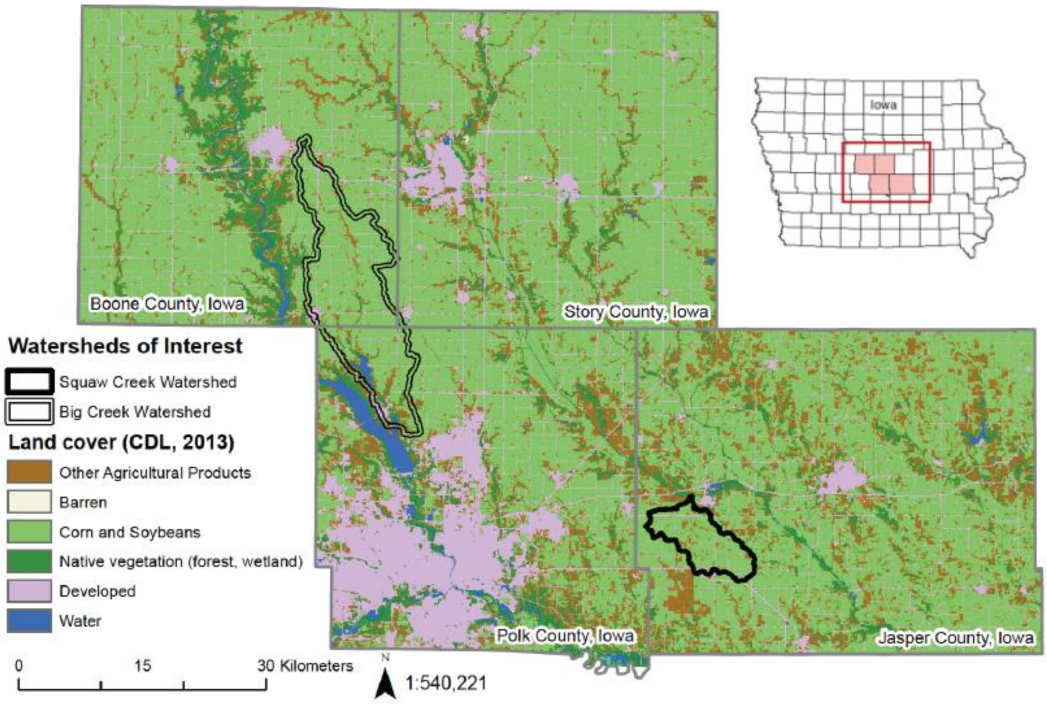

Figure 1. Map of location of Big Creek watershed (denoted in two black lines) and Squaw Creek watershed (denoted in solid black line) in four central Iowa counties (Boone, Story, Polk, and Jasper counties). Land use is derived from the 2013 Cropland Data Layer (USDA National Agricultural Statistics Service Cropland Data Layer, 2013).

Figure 2. Conservation map with a prairie strip (yellow line) integrated along the contour of a ~3% slope field to address issues related to nutrient and sediment loss due to overland flow. In addition to maps of soil, slope, and flow paths, farmer and farmland owner participants received a conservation plan outlining potential BMPs, like this one, for implementation on their fields. Conservation plans also included discussions about nutrient management and tillage, which are not represented on planning maps.

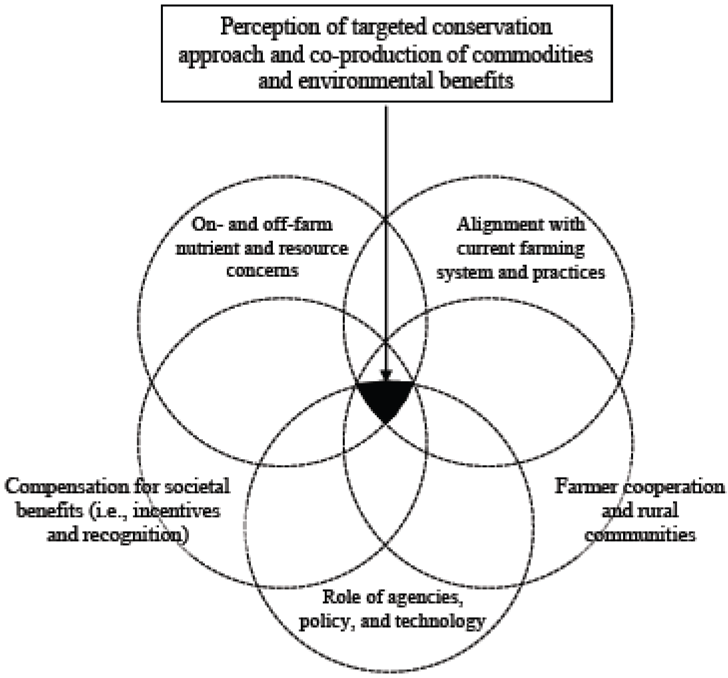

Figure 3. Five key themes emerged about interviewees' perceptions of a targeted conservation approach to expand the production of environmental benefits within agricultural watersheds. The five key themes are each represented by a circle. Each of the themes influences the perception of targeted conservation and the co-production of environmental benefits which is demonstrated by the shaded triangle in the center. As this diagram shows, themes are likely related and may be correlated, but the relationship among themes was varied and nuanced. Qualitative methodology precludes quantifying these relationships. Details revealed by interviewees are presented in the results section.